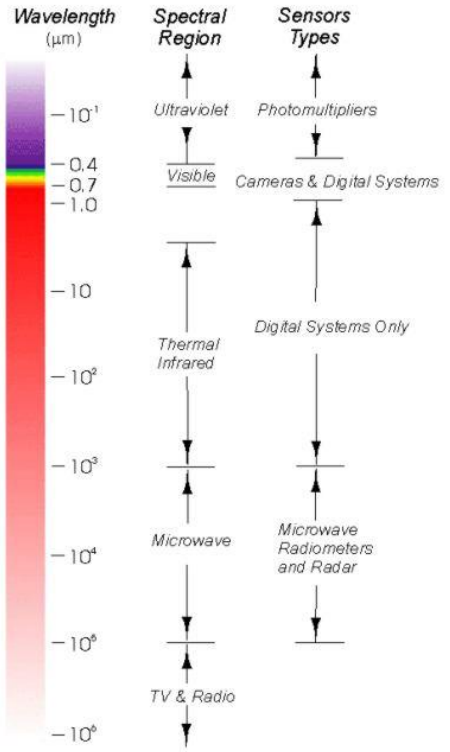
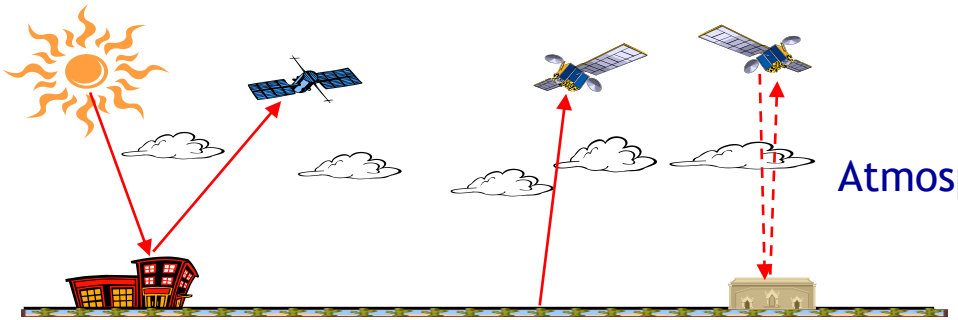
Remote Sensing and GIS

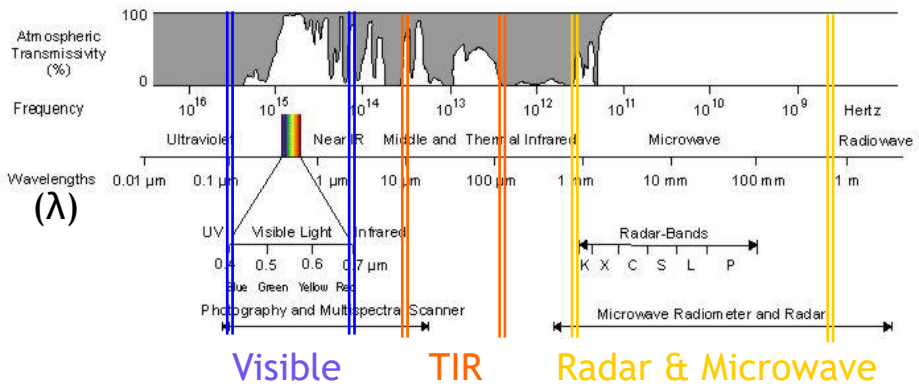




Reflected radiation, e.g. **Visible**

Emitted radiation, e.g. **Infrared**

Backscattered radiation, e.g. **Radar**



Definitions and Considerations

- Remotely sensed data – acquired without physical contact
  - Photographs and related data acquired by aircraft or satellite
  - Spectroscopy/Spectrometry
  - Principle advantages
    - Unbiased (nonselective) sampling
    - Rapid acquisition
    - Large footprints, synoptic bird's eye view
    - Acquisition of data spanning non-visible portion of the em spectrum; multispectral, multi-scale

Definitions

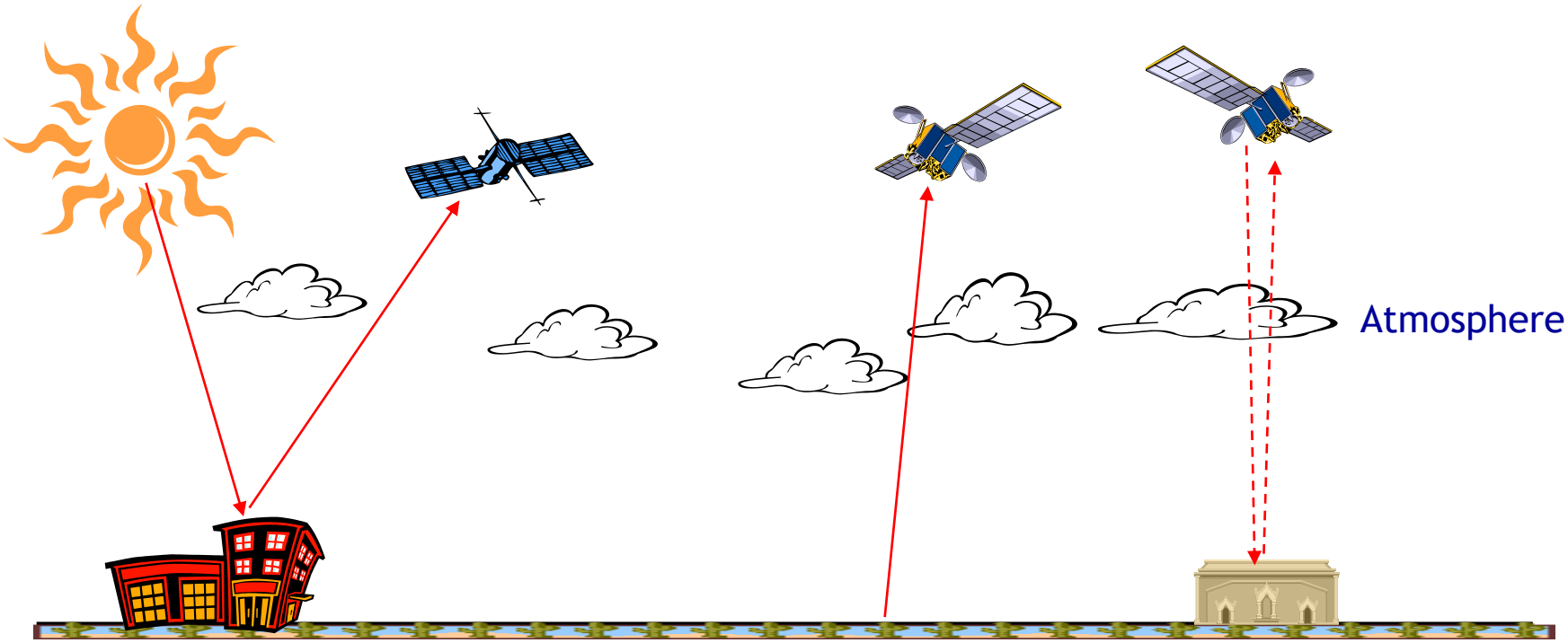
- Photograph – conventional picture by camera in the visible region of the em spectrum; analog
- Image, imagery – acquired by electronic detectors in the visible and/or nonvisible portion of the spectum; digital

Principle Land Mapping Applications

- Land Use/Land Cover, especially change over time– (categorical data)
- Planimetric location (x, y)
- Topographic/bathymetric elevation (x, y, z)
- Color and spectral signature
  - Vegetation biomass, chlorophyll absorption characteristics, moisture content
  - Soil moisture content
  - Temperature
  - Composition (spectrometry)
- Texture/Surface roughness

Principles

- Gather reflected, emitted or backscattered radiation



Reflected radiation,
e.g. **Visible**

Emitted radiation,
e.g. **Infrared**

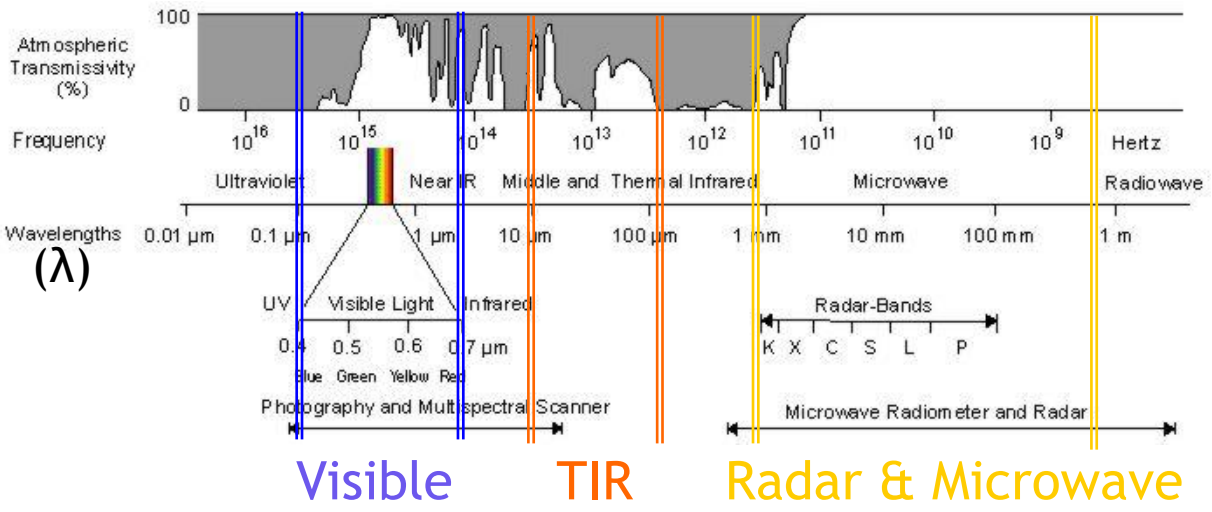
Backscattered radiation,
e.g. **Radar, Lidar**

Remote Sensing Classifications

- Passive – either analog or digital radiation *samplers*, e.g. cameras, TIR detectors, multispectral scanners
- Active – send out signal and record reflected radiation, e.g. imaging radar, synthetic aperture radar (SAR)
- Aerial platforms – e.g. aerial photography; large scale (<1:25,000)
- Space platforms – space station or satellite, e.g. SIR, Landsat; small scale (>1:750,000)

Atmospheric Attenuation and Scattering

- Scattering strongest at short wavelengths (blue sky: u.v. & blue scattered more strongly than rest of visible)
- Ozone absorbs x-rays & u.v., clouds scatter and absorb visible and I.R., except in certain windows, e.g. TIR
- Windows for radar and microwaves at 1mm – 1m wavelengths



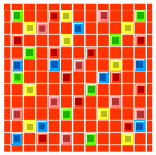
Interactions At the Surface

- **Reflection, absorption (±refraction & transmission)**
  - Absorbed energy re-emitted at longer wavelengths (e.g. thermal I.R.)
  - Reflection characteristics depend upon:
    - surface roughness (diffused and brighter for rough vs. mirror-like and dark for smooth)
    - amount of absorption ~ composition of material
  - Result is a complex "Tonal Signature"

Resolution Characteristics

- Four basics aspects of resolution:
  - Spatial

  - Spectral
  - Radiometric



  - Temporal

Spatial Resolution

- Spatial detail; sharpness of an image
  - Analog resolution:
    - Factor of resolving power of lens & film
    - Calibrate with line pair target. Best obtainable is ~ 60 line pairs/mm
    - Ground Resolution = scale factor/width of minimum resolved line

    E.g. For photo at scale of 1:10,000 and 60 lp/mm

    GR = 10,000/60 = 17 cm

Spatial Resolution

- Digital Image resolution
  - Function of detector characteristics (summarized by instantaneous field of view; IFOV) and height
  - Raster resolution (e.g. meters/pixel) is proxy for resolution, though at least 2 pixels are required to derive same content as analog image
  - Number of pixels required to achieve same resolution as best 9” x 9” analog aerial photo is ~700 megapixels! (c.f. “retina display” of ~8.6 Mpixels)

+ Geometric Fidelity

- Ability to know the location of any pixel in an image

Spatial Resolution Comparisons

10 meter resolution

5 meter resolution

Spatial Resolution Comparisons

2.5 meter resolution

1 meter resolution

Spatial Resolution Comparisons

1 meter resolution

50 cm resolution

Spatial Resolution Comparisons

25 cm resolution

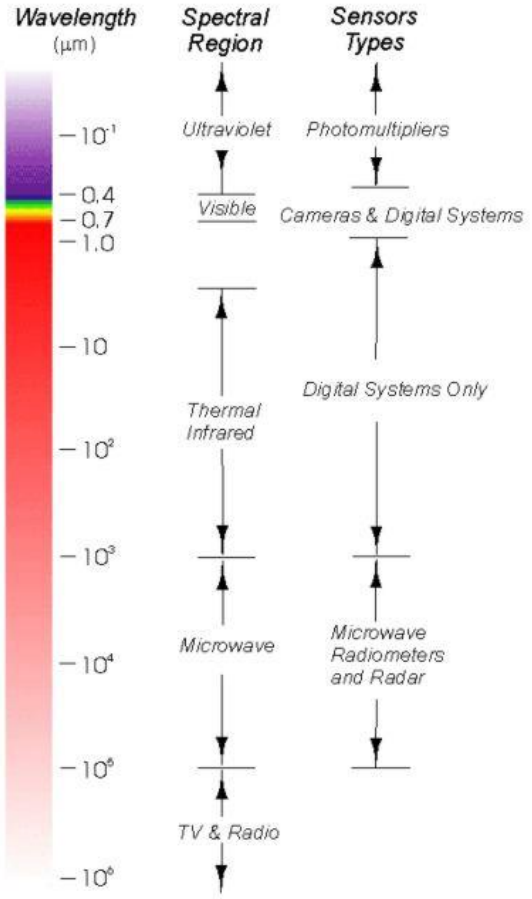
10 cm resolution

High Spatial Resolution Satellites

- Quickbird-2 (DigitalGlobe)
  - ~0.5m panchromatic, ~0.5m multispectral
- IKONOS-2 (Space Imaging, "GeoEye")
  - 1m panchromatic, 4m multispectral (4 bands)
- SPOT 6&7 (French Commercial Satellite)
  - 1.5m panchromatic, 6m multispectral (4 bands)
- Landsat 7 ETM+ & 8 (NASA/USGS)
  - 15m panchromatic, 30m multispectral
- EOS Terra ASTER radiometer (NASA)
  - 15m in three visible to near-IR bands
- Others

Spectral Resolution

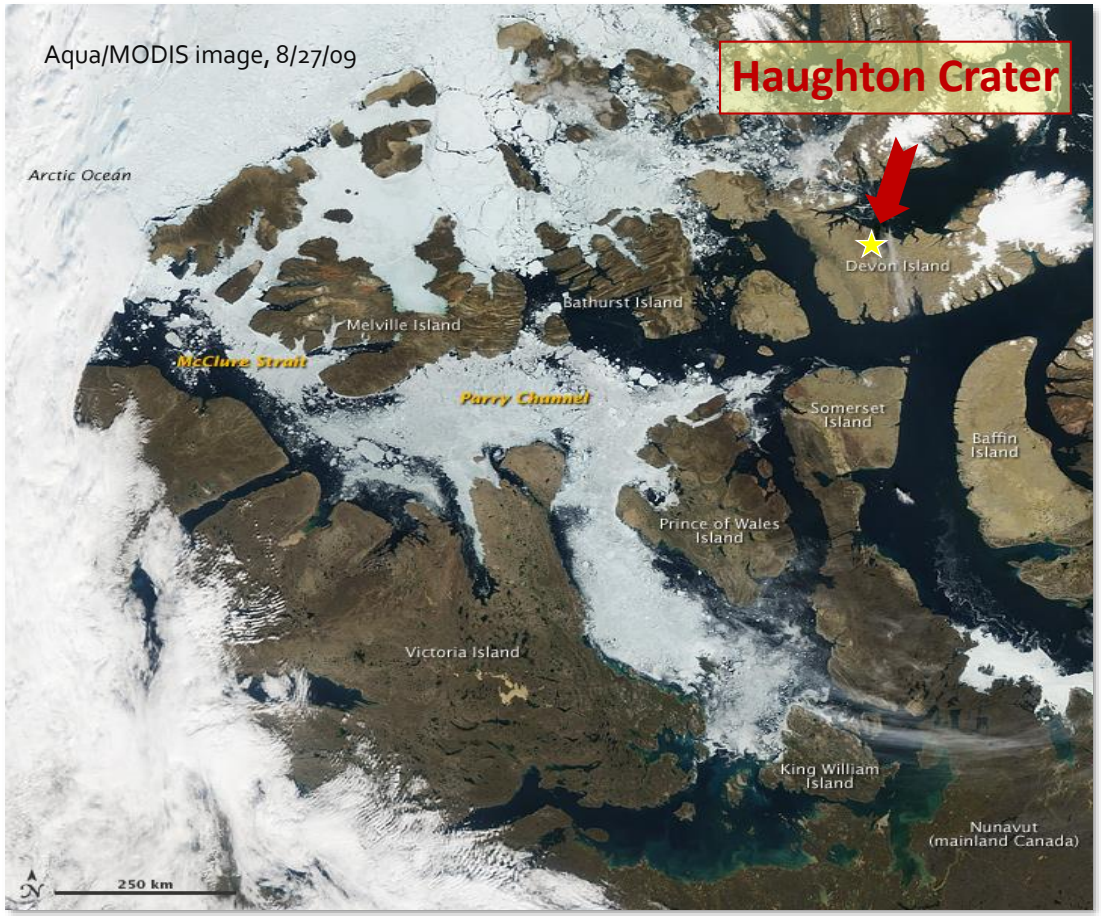
- Wavelength(s) to which the detector is sensitive. Depends upon:
  - Number of wavelength bands (channels)
  - Width of each band
- Low spectral res. – Panchromatic photograph; one wide band (~0.4-0.7m)
- High spectral res. = narrow bandwidth for many bands
  - e.g. EOS-Terra ASTER
    - 14 narrow bands that span visible to TIR (0.5-12 m)



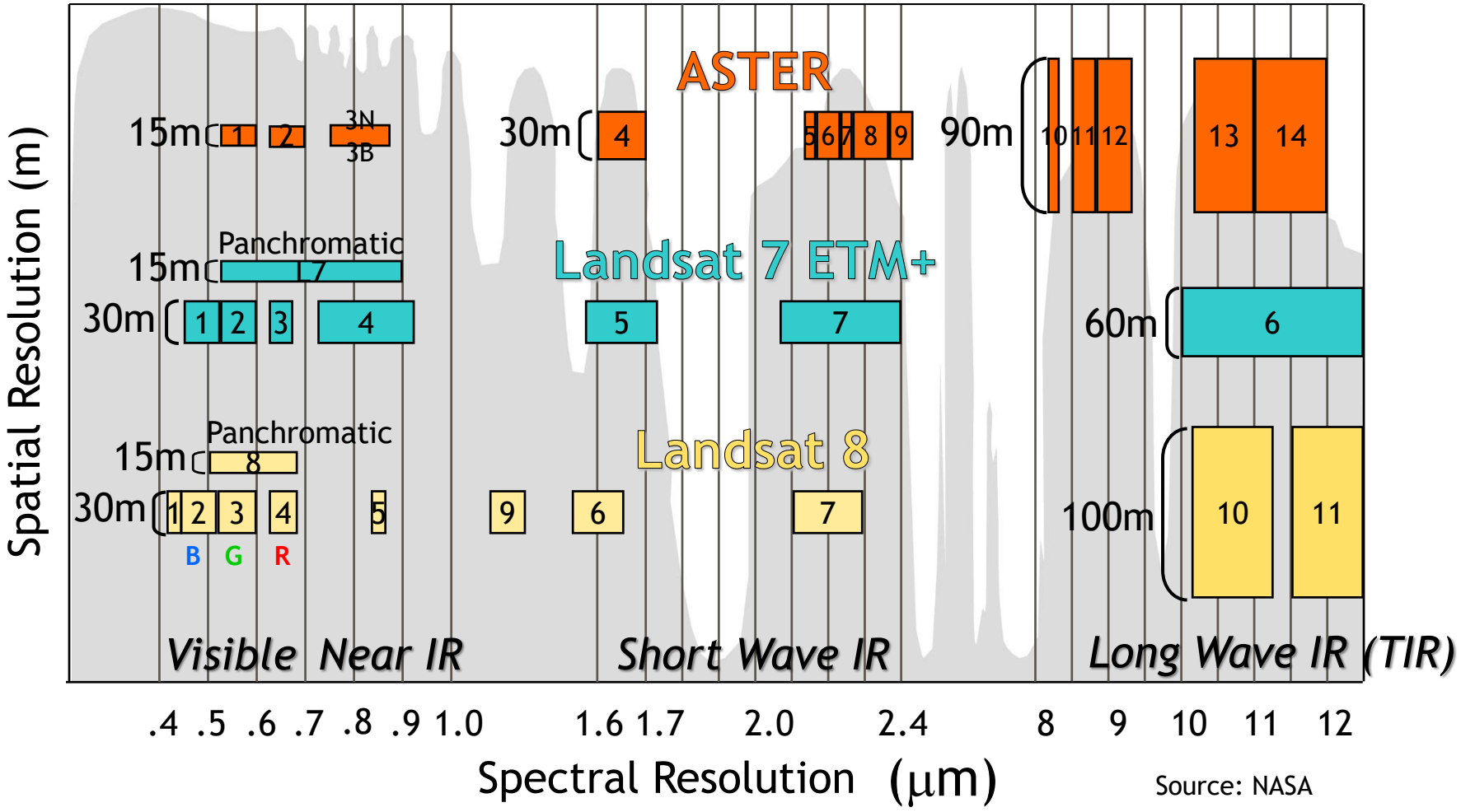
“Hyperspectral” Resolution

- = Very high spectral resolution
  - EOS-Terra and Aqua MODIS
    - 21 bands within UV to near IR, 15 bands within TIR, all with narrow bandwidths
    - Simultaneously observe cloud cover, sea and land temps., land cover, vegetation properties
  - EOS-Terra ASTER
    - 14 narrow bands that span visible to TIR
  - JPL AVIRIS
    - 224(!) narrow bands at 20-m spatial resolution from high altitude NASA aircraft

Aqua/MODIS


Aqua/MODIS image, 8/27/09
Haughton Crater
Arctic Ocean
Devon Island
Bathurst Island
Melville Island
McClure Strait
Parry Channel
Somerset Island
Baffin Island
Prince of Wales Island
Victoria Island
King William Island
Nunavut (mainland Canada)
250 km

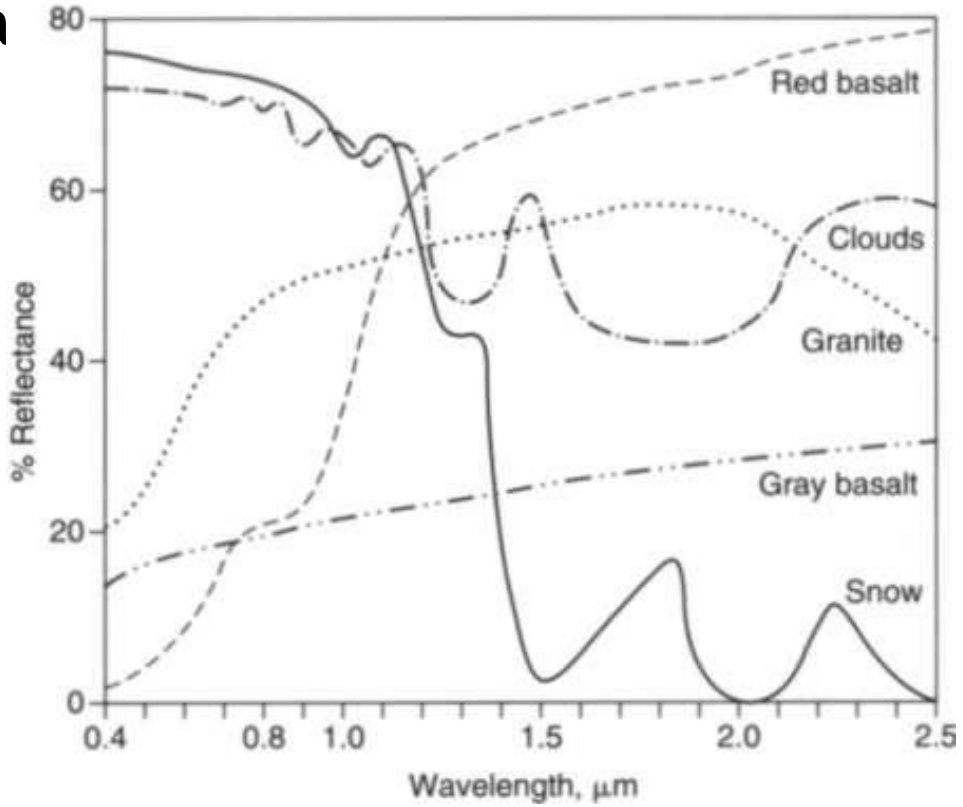
Spectral Resolution: ASTER, Landsat 7 ETM+ and 8



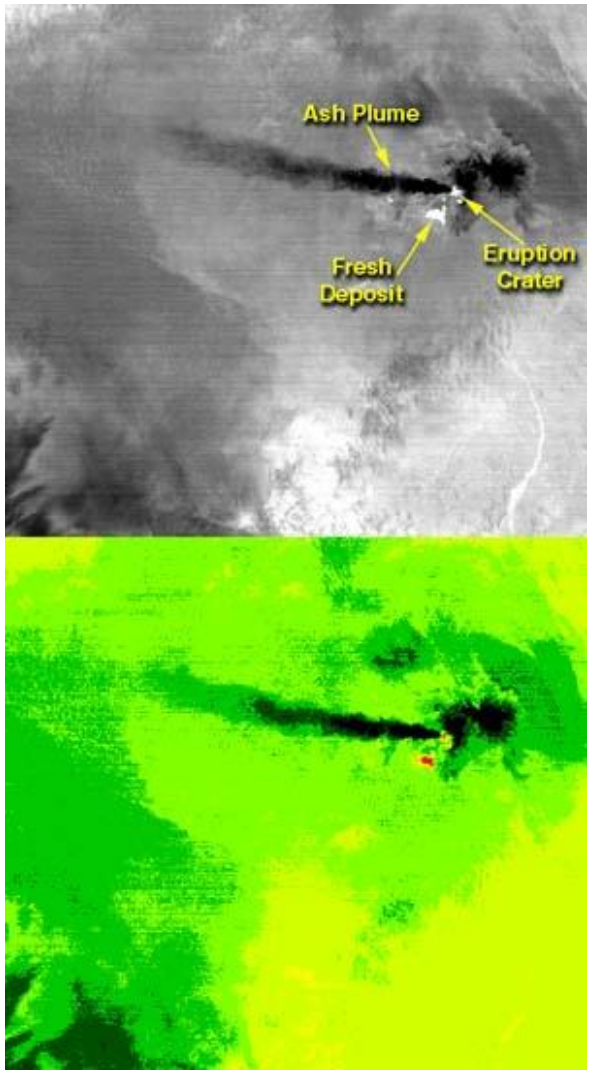
Source: NASA

Why High Spectral Resolution?

- Spectral reflectance is a sensitive indicator geology, water content, vegetation type, etc.
- Applications in ecology, geology, snow&ice hydrology, atmospheric sciences, coastal and inland waterway studies, hazards assessment



Example: Aster TIR Band Image



June 4, 2001 thermal image of Shiveluch volcano on Kamchatka Peninsula.

A lava dome is the hot spot visible on the summit of the volcano. The second hot area is either a debris avalanche or hot ash deposit.

An ash plume is seen as a cold "cloud" streaming from the summit.

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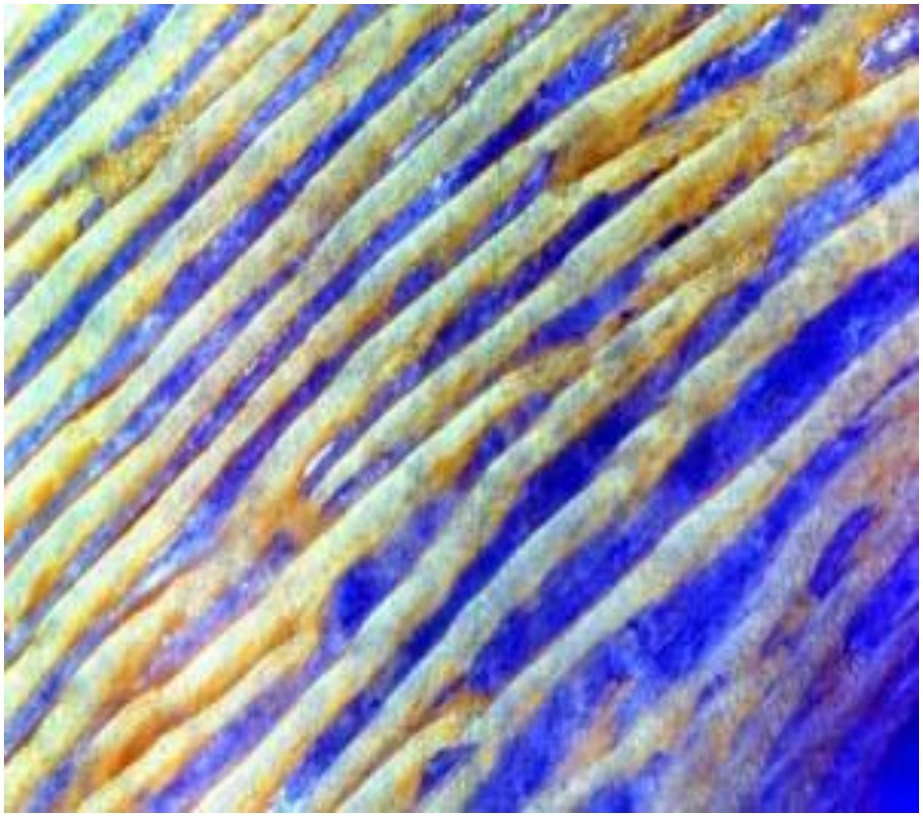
U.S./Japan ASTER Science Team

Example: Aster VNIR Band Image



Saudi Arabia sand dunes, 6-25-02

Depicts linear dunes in Rub' Al Khali or Empty Quarter in Saudi Arabia.

Dunes are yellow due to iron oxide minerals; inter-dune areas are made up of clays and silt and appears blue due to high reflectance in Band 1

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Example: Aster Band Image

Lake Garda, Italy - June 29, 2000

Lake Garda lies in the provinces of Verona, Brescia, and Trento. It is 51 km long and 3 to 18 km wide.

The image on the right was contrast stretched to display variations in sediment load

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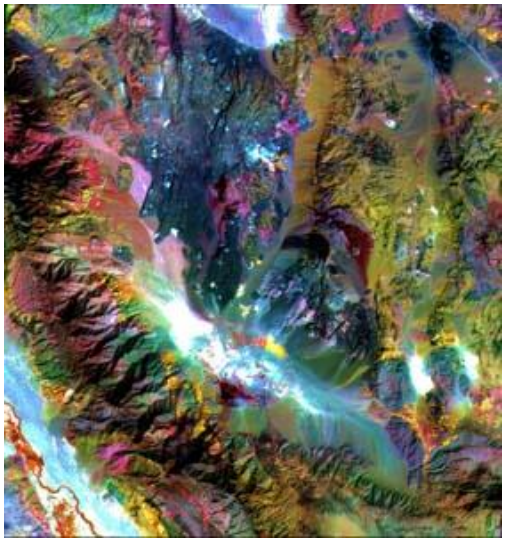
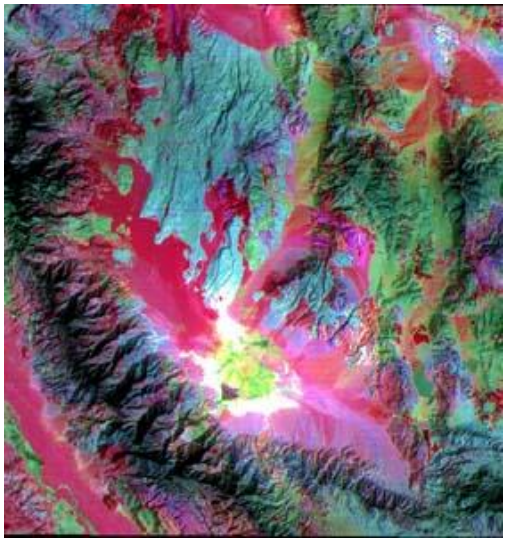
Aster Multi-band Band Images

VNIR



SWIR



TIR

Saline Valley, California

- VNIR (3,2,1) – vegetation appears red, snow and dry salt lakes are white, exposed rocks are brown, gray, yellow, and blue
- SWIR (4,6,8) – clay, carbonate, and sulfate minerals result in distinctive colors; limestones are yellow-green and kaolinite rich areas are purple
- TIR (13,12,10) – variations in quartz content are shades of red; carbonates are green and mafic volcanic rocks are purple

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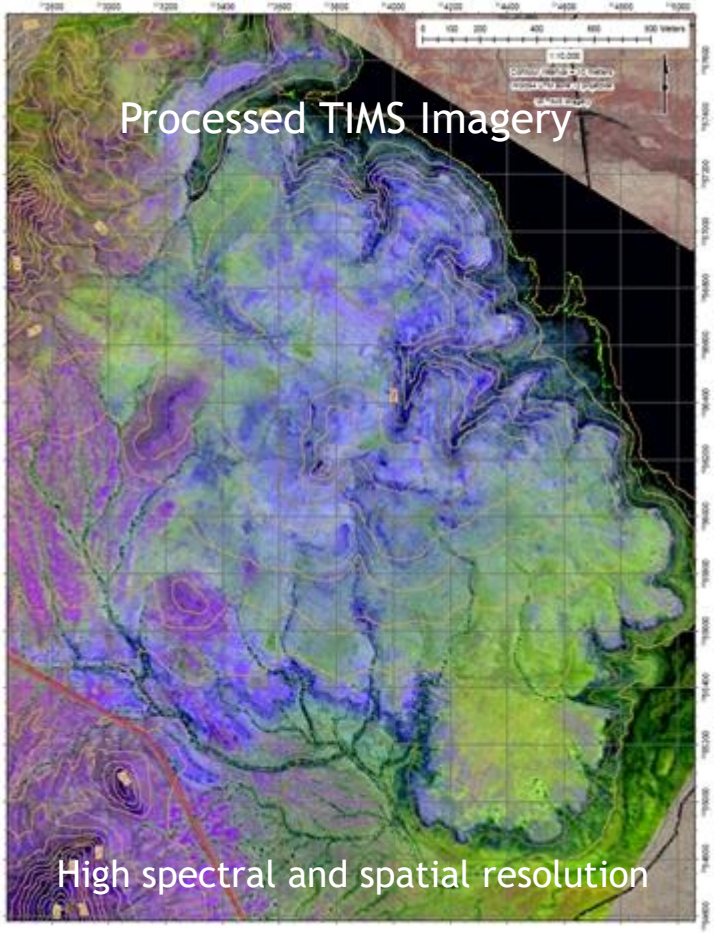
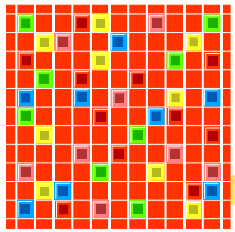
Thermal Infrared Multispectral Scanner (TIMS)

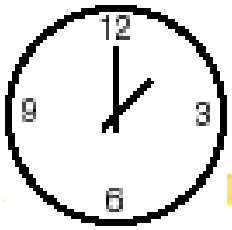
- Six spectral bands between 8-12 um
- ~2 meter resolution
- Processed so hues and tones record differences in quartz, olivine and carbonate contents





Radiometric Resolution

- Smallest detectable difference in radiant energy (intensity)
  - Analog – high contrast film has higher radiometric res. – more shades of gray resolved
  - Digital – number of (quantization) levels a band can be divided into; what is the possible range of values a pixel may obtain?
    - "7-bit" = 128 levels (Landsat MSS detectors)
    - "8-bit" = 256 levels (Landsat ETM+)
    - "12-bit" = 4095 levels (AVIRIS, Landsat 8)
    - "14-bit" = 16,384 levels (Landsat 9)



Temporal Resolution

- Frequency of data collection – time between repeated coverage
  - E.g. Landsat 5, 7, 8, 9 – 16 days
  - MODIS – 1 to 2 days
  - Higher temporal resolution yields better chance of cloud-free coverage
  - Match frequency with phenomena to be mapped